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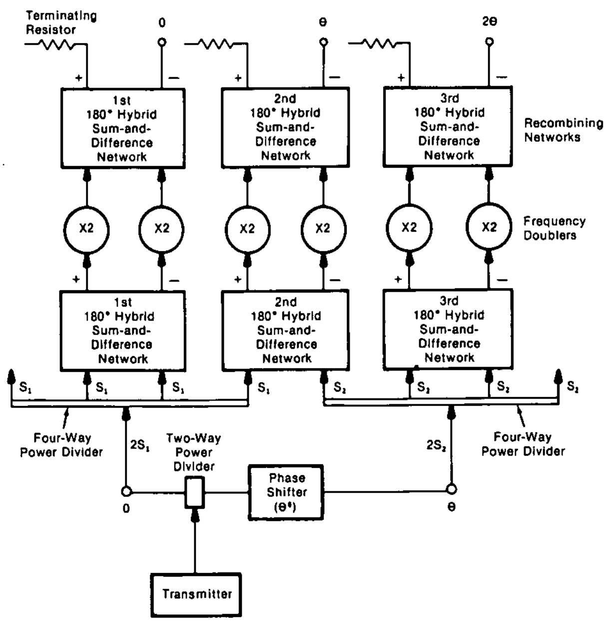
Phased-Array Antenna Phase Control Circuit Using Frequency Multiplication

The problem:

Phase control of a phased-array antenna is normally accomplished by an antenna coupling circuit. Thus a transmitter or a receiver, depending on whether the system is transmitting or receiving, is coupled to the antenna elements of the phased array through a power-dividing chain which has phase-shifting elements connected at some point or points in it. For instance, some previous phase controllers employ phase shifters connected at the ends of the power-dividing chains just prior to their connections with the antenna elements. Others have the phase shifters connected in series along the power divider chains. The major problem with such phase control circuits is that they are not accurate enough. More-sophisticated phase control circuits are capable of relatively-accurate phase control; however, in general they require expensive and nonstandard components.



Doubler Phase Control Circuit

The solution:

A new phase control coupling circuit uses frequency multipliers. The circuit separates out, from these multiplied signals, antenna element signals which have desirable phase angles and feeds them to the appropriate antenna elements of the phased array. The system may be used in either a transmitting or a receiving mode.

How it's done:

A frequency-doubling phase control circuit is illustrated in the figure. A signal supplied by the transmitter passes through the two-way power divider and the phase shifter to terminals 0 and Θ. Thus a signal ($2S_1$) which has zero relative phase shift appears at terminal 0, and a signal ($2S_2$) with a relative phase shift of Θ^0 appears at terminal Θ. Assuming a pure sine wave signal, these signals are given by

$$2S_1 = 2\cos\omega t$$

and

$$2S_2 = 2\cos(\omega t + \Theta)$$

where t denotes time in seconds, ω is the angular velocity of the signals, and Θ is the angle by which S_2 leads S_1.

Each signal is fed to a four-way power divider having input-to-output amplitude ratios of 2. Thus the outputs of these dividers are S_1 and S_2, respectively. One four-way power divider connects signals S_1 to the first and second inputs of a combining 180° hybrid sum-and-difference network and to the first input of a second such network. Signals S_2 are connected similarly to the second input of the second network and to the first and second inputs of a third 180° hybrid (see figure). The fourth output of each power divider is connected to other hybrids which, for simplicity, are not shown.

(continued overleaf)

The combining hybrids each have a sum port and a difference port. Thus the sum signal from the second 180° hybrid is given by $(S_1+S_2)/\sqrt{2}$, and the difference signal is given by $(S_1-S_2)/\sqrt{2}$.

The sum-and-difference ports of each hybrid are connected to frequency doublers, the outputs of which are proportional to the square of their inputs. The doublers connected to the second hybrid, for example, have the outputs $(S_1+S_2)^2/2$ and $(S_1-S_2)^2/2$. Finally, the sum-and-difference frequency doublers of the first 180° hybrid are connected to the first and second inputs of the first recombining 180° hybrid network, those of the second hybrid are connected to the inputs of a second recombining network, and those of the third hybrid are connected to the inputs of a third recombining network.

The difference ports of the three recombining networks feed active antenna elements, while the sum ports are applied to terminating resistors. The outputs at the difference ports of the three recombining networks are proportional to

$$\sqrt{2}\, S_1S_1, \quad \text{(1st)}$$
$$\sqrt{2}\, S_1S_2, \quad \text{(2nd), and}$$
$$\sqrt{2}\, S_2S_2; \quad \text{(3rd)}$$

corresponding to signals given by

$$(1/\sqrt{2}) \cos (2\omega t),$$
$$(1/\sqrt{2}) \cos (2\omega t+\Theta), \text{ and}$$
$$(1/\sqrt{2}) \cos (2\omega t+2\Theta).$$

Thus the doubler phase control coupler circuit provides three outputs, each having a frequency of $2\omega t$, which is double the frequency of the input signals S_1 and S_2. The first output signal has a zero relative phase shift, the second has a relative phase shift of Θ, and the third has a relative phase shift of 2Θ.

A unique feature of the doubler phase control circuit is that it may be used even when the frequency doubler conversion loss is a variable function of the power input. Thus the doubler phase control circuit yields phase-shifted signals which are shifted one from the other by highly accurate increments. Moreover, the circuit employs standard, interchangeable components and is relatively uncomplicated. Finally, the principle of the doubler phase control circuit may also be used for more generalized phase control circuits which use higher orders of multiplication to produce a greater number of phase-shifted output signals.

Note:

Requests for further information may be directed to:

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Patent status:

This invention has been patented by NASA (U.S. Patent No. 3,710,329). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to:

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Categories: 01 (Electronics - Components and Circuitry)
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